SOME REMARKS ON

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MR. PRESIDENT: At our last meeting I had the honor of reading before the members of the Society a paper on Relative Accommodation.[1] My remarks at that time referred almost exclusively to the physiological connection between convergence and accommodation in the normal eye. It is now my desire to lay before you, as briefly as possible, some points which seem to me to be of practical importance in regard to the manner in which these two muscular forces react, or may be made to react, upon each other in strabismus and insufficiency of the recti muscles.

It may be stated as a general law that, within certain limits, by increasing or decreasing the convergence, the amount of accommodation is also increased or diminished.

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[1] Relative Accommodation. Trans. American Oph. Soc., July, 1868.

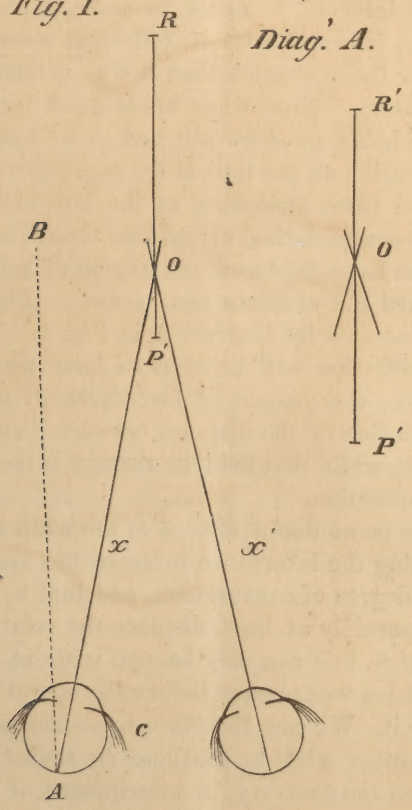
It was in accordance with this law that the practice, adopted by the earlier practitioners, of dividing the recti interni in those cases of asthenopia where there was no strabismus, often met with success. This was at a time when the errors of refraction were not understood as they now are, and when the true nature of hypermetropia and its results had not been recognized. At a somewhat later period Donders, with his vast and exact knowledge of the whole subject, could not refrain from characterizing this practice of dividing the interni, where there was no squint, as a "melancholy page in the history of ophthalmic surgery," while on the other hand no less an authority than Von Graefe not only sanctioned this division of the muscles under these conditions, but had even performed it on two occasions.

His justification of the operation and explanation of its modus operandi are so admirably given, and so essential for a correct understanding of what is to follow, that I will briefly read them to you in his own words. Von Graefe, speaking of the treatment of asthenopia in hypermetropic eyes, in which, however, there is no strabismus, says: "There is still another cure for asthenopia which is founded on the displacement of the relative accommodation. If we weaken by a suitable tenotomy of the internus its effective ability, in such a way, however, that a correct position of the eye operated upon shall still be maintained, then every given degree of convergence will be represented by a greater tension of the interni than that existing before the operation, and a corresponding displacement of the region of the relative accommodation toward the absolute near point will be the result. The demands on the energy of the accommodative force will consequently be less." (Arch. 8., ab. ii., s. 320.)

The principle involved in this statement is so important to the subject under consideration, that I would call your attention for a moment to the diagram which I have drawn upon the board (Fig. 1), which is supposed to represent the condition taken by Von Graefe, that is to say, a pair of hypermetropic eyes suffering from asthenopia, but in which there is no

strabismus. x and x' represent the optical axes, both of which intersect each other at the object viewed, o, supposed to be at 14 inches from the eye. In all hypermetropic asthenopic eyes

Fig. 1.



Diag. A.

the amount of accommodative force actually used is greater than that which is held in reserve. The amount used in this case may be represented diagrammatically as extending on the vertical line from the point o to the point R′, that held in reserve as extending from o to P′.

If we now divide one of the interni, say the left, c, a certain amount of divergence of the optical axis, x, from its former

position would be the immediate result, exactly as it is in the common operation for strabismus. This divergence may be represented on the diagram by the dotted line extending from the point B to the point A, and it is self-evident that the tension on the internus, in order to make *x* regain its former position—*i. e.* intersect with its fellow at *o*—must be as much greater, after the operation than it was before, as the divergence is greater. Now what holds good for one degree of convergence holds good for all; and as we have increased the amount of tension on the interni for every given degree of convergence, we have, according to the law, also increased the amount of accommodation, or, as Von Graefe more exactly expresses it, we have displaced the region of relative accommodation toward the absolute near point. This displacement may be represented by diagram A in Fig. 1. The whole relative accommodation will be seen to have been displaced toward the eye; the amount of force actually expended, represented in the line by the distance between *o* and R', is seen to be much less, while that held in reserve is much greater than before the operation.

There can be no doubt then as to the truth of the statement that by cutting the interni we increase the amount of tension for a given degree of convergence, and that by so doing we do indeed, temporarily at least, displace the relative accommodation. But then this can only happen without exception, when binocular vision was present before the operation and is maintained after it. We can, therefore, by no means agree with the illustrious author when he continues by saying:

"When, on the contrary, in consequence of hypermetropia, convergent squint has resulted and characterizes the patient, not only at work, but at other times, I am then an advocate for tenotomy, which then in all respects appears rational. The better position of the eyes, which is obtained by the operation, will, *since a greater tension of the interni is represented, exercise the same effect on the range of relative accommodation as did the original condition of the convergence*, which was not only disfiguring, but which threatened the functions of

the organ for continuous work."[1] (Arch. 8, ab. ii., s. 321, note.)

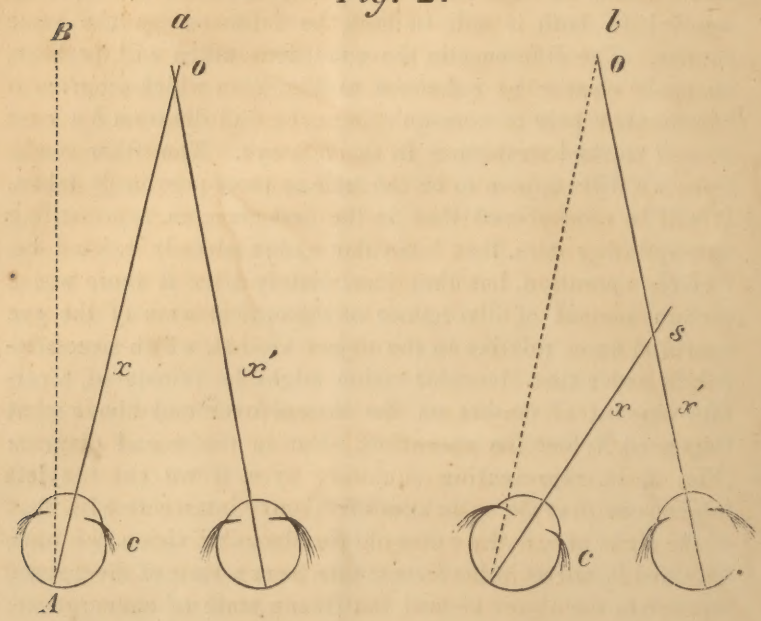
Now the conditions in the two cases taken by Von Graefe, namely, squinting and non-squinting eyes, are not the same, and we have no right to assume that if the same principle be applied to both it will in both be followed by the same results. The difference in the conditions taken will, perhaps, be made clearer by reference to Fig. 2, in which diagram *a* represents a pair of non-squinting eyes, and diagram *b* a case of well marked strabismus in the left eye. The other conditions we will suppose to be the same as those previously taken. It will be remembered that in the first diagram, representing non-squinting eyes, that binocular vision already existed before the operation, but that immediately after it there was a certain amount of divergence of the optical axes of the eye operated upon relative to the object viewed, which necessitated, in order that binocular vision might be reinstated, a certain amount of tension on the interni over and above what they used before the operation. But in the second diagram (Fig. 2, *b*), representing squinting eyes, if we cut the left internus so that the optic axes of this eye intersects with that of the right at *o*, and we thus obtain binocular vision, we have obtained it, not as in the former case, from a state of divergence relative to the object viewed, but from a state of convergence; so it will be seen that the conditions are at the outset very different. But in order to understand the question fully it will be necessary to recur briefly to the principle or law upon which the assertion is founded—"That after a tenotomy a greater tension of the interni is represented, with the same effect on the relative accommodation."

This depends upon a law propounded by Von Graefe some years ago, that the effect of a tenotomy is in exact relation to the amount of displacement of the insertion of the muscle. That is to say, a convergent strabismus of three lines will be removed by setting back the insertion of the muscle three lines, etc., etc. This law is founded on mechanical principles, and is perhaps as correct as the application of any mechanical

[1] The italics are my own.

formula to the human organism can be, where the conditions in no two cases are ever alike, and where they are constantly varying in the same individual case.

Fig. 2.



In order to explain this theory it was assumed that the amount of labor imposed upon the interni increased *pari passu* with the displacement backward of the insertion of the muscle, so that, although the convergence is lessened by the operation, the tension on the interni demanded to maintain this convergence is as great or even greater than before the operation. Admitting even that this is *per se* true, we must not forget that in estimating the power of a muscle which has a direct antagonist we must also take into consideration the force of this antagonist, and bear in mind that if the conditions under which one performs its functions are altered, those of the other are changed also. It must be remembered too that in squinting eyes, just as in others, there is a certain amount of tension on the internus of the eye which turns in, which is counterbalanced by a certain amount of tension of the externus.

Now the effective power of the externi increases with the amount of the convergence, and it must follow that the externus of a squinting eye, other things being equal, is in a better position to lay out whatever power it may possess, than in the case where there is a normal intersection of the optic axes. So it may happen that although the tension demanded of the internus after it has been set back would naturally be the same or even greater than before the operation, yet the ability to oppose this tension on the part of the externi is not as great as it was before, from the comparatively disadvantageous position under which their effective force is applied. That is to say (referring to the diagram, Fig. 2, *b*), it requires a greater effort for the externi to counterbalance a given amount of tension under a correct position of the axes, *x* intersecting with its fellow at *o*, than it previously did under an abnormal degree of convergence, when *x* intersected with its fellow at *s*.

Now if from any cause the externi are idiopathically weak, then their inability to resist the tension of the interni when accommodation is going on may be so great that a proper intersection of the visual lines can only be maintained after the operation, in case the opposing tension of the interni is reduced or even entirely relaxed. If this is true, then we ought to expect, according to the law, that if the tension on the interni is reduced the relative accommodation will not be, as Graefe asserts, displaced toward the near point, but be removed from it. And as a proof that precisely this may take place, and, as I believe, not unfrequently does where binocular vision is obtained, I would beg leave to refer to the following case, recently under the care of Dr. Agnew and myself.

About the first of last May a young lady, 19 years of age, visited us on account of strabismus, with which she had been affected from early childhood. The squint, amounting to about $3\frac{1}{2}$ lines, was perfectly concomitant in its character, as either eye was used indiscriminately, though the patient could always tell, if her attention was called to it, which eye she was for the moment employing. The total hypermetropia under atropine amounted to 1-36, vision being with suitable glasses a little less than one. But though there was this amount of vision in either

eye, no binocular vision in any proper sense of the term could be called forth, though many attempts to produce it were made with prisms, colored glass, Javal's mirror and the stereoscope. The accommodation was normal, as was also the excursion of the eyes, independent of the existing squint. As there was not the slightest contra-indication, and as the cosmetic effect was the only consideration which weighed at all with the patient, the rectus internus of the right eye was divided. As the necessary effect was not obtained by this operation, the other eye was operated upon six weeks later. I will add that, on both these occasions, the tendon was thoroughly separated from the sclera. About the first of October the patient again returned. The effect which had been gained by the last operation had entirely passed away, there remaining about a line of convergence for distant objects and something more for the near. Another attempt was made to see whether binocular vision could not be called forth, but without success. The patient seemed to have, to a marked degree, what is called in the text-books the "horror of binocular vision." As diplopia would not in all probability be caused, even if a slight divergence should be produced, it was determined to run the risk of a third operation, which was consequently performed.

The effect of this operation, after the wound had healed, was not as great as had been feared, only a very trifling degree of divergence being produced, which soon passed away for distant objects, while there still remained a perceptible convergence for the near. I found, however, that there was now an attempt on the patient's part at binocular vision; that once or twice while looking at distant objects she had seen them double. I then gave her Javal's mirror, with which she practiced faithfully for two months, at the end of which time she was able to see, as a constant thing, the three wafers in a vertical line, and was perfectly aware when she was using binocular and when monocular vision. She then informed me that latterly, since she had been conscious of using both eyes at a time, she did not see as distinctly as she formerly did; that she could not read at all when using both eyes, and that even in the street every thing was indistinct, and that she frequently had to shut her eyes, and on opening them again to use only one. When she

did this vision became distinct at once. This led me to make another examination as to the amount of vision and state of the accommodation. I found that when using both eyes at once vision was only 1-5; but with either eye singly it amounted to nearly 1. If, however, + 1-36 (the amount of the total H.) was given to the patient then binocular vision fully equaled, and I thought a little surpassed, the monocular, rising from 1-5 to nearly 1. So too in reading it was found that + 1-10 was the weakest glass through which there was easy and rapid binocular vision at 14 inches. (This convex 1-10 just represented the total H., 1-36, and the distance of the object seen, 14 inches.) Each eye singly, however, could read correctly at 5 inches without the aid of any glass, though only when its fellow deviated inward, the amount of this deviation decreasing with the strength of glass used till it entirely ceased under + 1-10.

It will be seen from the above that under binocular vision, and what may be certainly termed "a better condition of the optical axes," not only was the relative accommodation not displaced toward the absolute near point or remain as it was before the operation, but was removed from it, and that too to such a degree as to be annihilated, no accommodation at all remaining for any given degree of convergence from the negative far point (Ht. 1-36) to the nearest point of binocular vision at which the eyes were still accommodated for convergent rays.

But it may be said that the operations themselves had in some way so destroyed the relationship between the accommodation and the convergence that the former could not be brought into play. Admitting that this is just what did take place, it does not follow that this result is due simply to operative interference, for precisely the same thing may take place even when no operation has been performed; for Schweigger, in his remarkable monograph on strabismus, gives a minute report of a case of squint of four lines, in which binocular vision was obtained by systematic exercise with prisms. In this case, as in the one just reported, the total hypermetropia at once became manifest as soon as binocular vision was obtained, and the field of accommodation was so far removed that even with a convergence to eight inches the eyes still remained accommodated for convergent rays. (Zehender, Jan.–Feb., 1867, p. 8)

In summing up the remarkable points of this case Schweigger mentions, as two of its individual peculiarities, that under the influence of binocular single vision the previously existing latent hypermetropia became manifest, and that the relative accommodation was displaced. I cannot think that these are by any means individual peculiarities of this particular case, as I have myself not unfrequently seen the latent hypermetropia become manifest after the operation, but have also occasionally seen the displacement of the relative accommodation, and believe that we should see it oftener if we examined carefully for it *immediately* after the operation; but the fact is, it is a much rarer thing to obtain real binocular single vision in a case of marked strabismus than we should be led to suppose from the books. I cannot think that results as remarkable as those mentioned in Schweigger's case and the one just described can be the result of chance, but believe that they are due to the common law which governs the connection between convergence and accommodation.

It seems to me that these two cases offer a beautiful example of the law sought to be established in my former paper, that for every increased tension of the ciliary muscle there is a corresponding and contemporaneous tension imparted to the interni. For, provided that accommodative efforts ceased, and the ciliary muscle consequently entirely relaxed, the externi, stimulated by the instinctive desire for binocular vision, had force enough to obtain the proper position of the optical axes, but not enough to *maintain* it, under the action of the ciliary muscle; for the slightest attempt to accommodate the eye, even for parallel rays (Ht. being only 1-36), at once destroyed binocular vision, producing convergent strabismus. This certainly could not have been the case had the tension of the ciliary muscle been independent of—that is to say, capable of being disassociated from—the interni. And I believe in all cases where binocular vision has been obtained from a condition of marked strabismus, that the reason why it is permanently maintained is not because the tension of the ciliary muscle is disassociated from that of the interni, but because the tension, imparted to them under accommodative efforts which would turn the eye in, is counterbalanced by the externi,

their natural antagonists, which keep the eyes straight. Now the desire for binocular vision and the power of the externi to fulfill this desire, vary exceedingly in different individuals, which accounts for the ease or difficulty with which, other things being equal, they obtain and maintain binocular vision, and neutralize any effect which the operation may have had on the relative accommodation.

There are very many points in this connection which I would gladly dwell upon, did not the limits of these remarks and a proper regard for your patience forbid.

The particular point of practical importance to which I wished to call your attention, and to arrive at which I have taken what may appear to you a needlessly long route, is this. *That where we have obtained binocular vision from a state of squint, we cannot tell what glasses may be necessary for its easy maintenance, even when we know the exact state of the refraction and the amount of monocular accommodation before the operation.* Take the case in question. Here there was only a total hypermetropia of 1-36 with a monocular accommodation of 1-4, and it might surely be supposed that binocular vision might, with so slight an error in refraction and such a range of accommodation, be maintained without any glass at all, or at the most with a correction of the total hypermetropia. But it not only required that this should be neutralized, but a very strong glass in addition, a convex 1-10 being the weakest glass which made binocular reading possible at 14 inches, which is over three times the amount of the total hypermetropia. So, too, in Schweigger's case, where the glass required for 8 inches was more than twice the total H.

May not the above fact explain the reason why convergent squint is so apt to recur after an operation even in emmetropic eyes, and why also we find it so difficult to obtain binocular vision in such eyes, especially for near work? And ought not such cases to point out the necessity for ascertaining at once what effect the operation has had on the relative accommodation? And if the effect has been to diminish and displace it outward, the deficiency should at once be supplied by the proper convex glasses, which should be gradually reduced in strength as the patient learns to associate a larger amount of

accommodation with a smaller degree of convergence than he has been in the habit of doing; that is to say, till he learns, for the sake of binocular vision, to oppose the tension on the interni by a counterbalancing effort on the part of the externi.

The best result which can be obtained after a tenotomy is, of course, binocular single vision, and this result should always at least be aimed at, even though there be a large amount of amblyopia in the squinting eye; for, by a correct intersection of the visual lines, the combined field of vision of the two eyes is increased in size, for the images formed upon the retina of the amblyopic eye, though not intense enough to produce real binocular single vision, are yet quite enough to give the patient perception of objects situated laterally, and thus free him, to a considerable extent, from the necessity of that continual turning of the head common to those who have only monocular vision. It is indeed asserted that even in its abnormal position the squinting eye often renders important aid, not only in lateral qualitative perceptions, but even in increasing the intensity of the impressions of the fixing eye. (Graefe.)

There is a great discrepancy among authorities as to the frequency in which binocular vision is obtained after tenotomy—Graefe and others putting the percentage as high as fifty in the hundred in its favor, while Stellwag boldly asserts that binocular single vision is scarcely ever, if ever at all, obtained.

It is manifest that both these statements are extreme, and that if, on the one hand, Graefe's statistics are, as Stellwag claims, made up on entirely untrustworthy data, his own are deduced from results given by tests which are entirely too severe. I allude to the so-called falling test of Hering. It is certainly any thing but fair to expect that a person who has been accustomed, perhaps all his life, to judge of distances with one eye with the assistance of surrounding objects, should, when these are excluded, be able, even when using two eyes, to obtain at once, after an operation, as keen a perception of perspective as those who have always possessed binocular vision.

Without at present entering further into this subject, I feel convinced that we often obtain a fair, sometimes even a very

large amount of binocular single vision—quite as much and sometimes more than is to be found among those whose optical axes have always intersected in a normal manner, but yet where, for some reason, one eye was amblyopic, as among those, for example, who have a large discrepancy in the refraction of the two eyes. For in these cases not only does the most ametropic eye always extend the field of vision, but often aids materially, even when the discrepancy is of a considerable degree, in the patient's estimation of perspective. This being the case, we should always endeavor by every means in our power, therapeutical as well as surgical, to obtain for the squinting eye as large a share in the common act of vision as possible, and should never be satisfied, as many are, with simply obtaining a good cosmetic result.

We can all of us call to mind numerous cases in our own and in our colleagues' practices where the intersection of the visual lines appeared perfect and where there was acute vision in both eyes, but yet where there was no single binocular vision; and I fear that most of us have been in the habit, after a few or perhaps without any trials with prisms, etc., of sending such patients away, quite as much elated by our own prowess in doing a tenotomy as the patient is by an improved personal appearance, and each as indifferent as the other whether vision is performed with two eyes or one.

The remarkable manner in which some patients will regain and maintain binocular vision, even after this has been lost for years, is too well proved by authenticated cases to need much comment. To show, however, that it may be often brought about by simple therapeutical means, and to illustrate some further points, I beg leave to cite the following case.

Miss L., some five years ago, had been operated upon for what she characterized as a "fearful squint." There had been two operations on the right and one on the left eye. The deformity seems to have been entirely removed, the optic axes apparently intersecting at the object viewed. The patient simply complains now of asthenopia. Vision is 1, in both eyes, though there is no binocular single vision. After a good many trials with prisms, Javal's mirror and the stereoscope, the patient was finally brought to have double vision, the

images being invariably homonymous, and separated about 10° of prisms in twelve inches. Paralysis of the accommodation showed hypermetropia = 1-9, though the patient had previously been wearing + 1-36. This would account for the asthenopia. After the atropine had passed off I ordered 1-18 for the distance and + 1-12 for the near, and she was to wear the glasses as constantly as possible. Shortly after putting on the glasses the patient came back to me complaining that the pain was greater with the + 1-18 and 1-12 than it had been with the convex 1-36. She wished to give up the glasses, as they were "too strong for her;" but I assured her that the pain which she had experienced was not because her glasses were too strong, but because they were too weak. I then told her to wear convex 1-12 continuously. After a little while she again returned, saying that the pain had been intense and constant, and that she could not wear such strong glasses. Thinking that the patient might have that intolerance of strong glasses which some hypermetropes of a high degree often show, I determined to reduce their strength. I found now, however, on examination, that the patient had easy and perfect binocular vision, and that a prism base upward gave vertical images throughout the range of accommodation, whereas in my former examination the images were homonymous, 10° in 12 inches. At the distance, however, the images were at times slightly homonymous, and the actual adductive power still preponderated greatly over the abductive, all through the range of accommodation. Thinking that the attempt to maintain binocular vision and the consequent strain on the externi was what had occasioned the pain, by giving rise to muscular asthenopia of these muscles, I encouraged the patient to continue with the glasses. Three months later the pain had almost ceased, while the condition of the muscles was as follows. At 20 feet, with no positive glass, but with the colored slide, there was an insufficiency of the *externi* equal to a prism of 12°. If + 1-18 was added the insufficiency sank to 3°; if + 1-12 then the images are exactly vertical and remain so throughout the range of A. The adduction at 20 feet (with the convex glasses) is 5°, while the abduction amounts to 7°. At 12 inches the adduction is only equal to 8°, while the abduction

amounts to 15°—the preponderance of power now lying two to one with the *externi*, which is exactly the reverse of what it should be in the normal eye. Thus in less than six months, by simply using suitable glasses, binocular single vision was obtained throughout the range of accommodation, and the patient, from having an insufficiency of abductive force of 10° for 12 inches, obtained a positive abductive power of 15° for the same distance—a clear gain in the power of the externi of 25°, as measured by prisms. This gain is no doubt due to the fact that as the ciliary muscle relaxed under the glasses, the tension on the interni which had always been associated with it was also gradually relaxed, thus *pari passu* increasing the power of the externi, even after binocular single vision had been regained.

So great a gain as this in the power of the externi would lead us to fear that the excess of power, at first apparent in the interni, was not due to their intrinsic strength, but rather to the reflected or associated force from the ciliary muscle under the excessive tension imposed upon it in order to overcome the error in refraction.

We cannot but fear that, where the abductive force for the greater part of the range of accommodation is nearly twice as great as the adductive, that the original and intrinsic power of the muscles has been weakened by the operations; so much so, indeed, that we may be justified in fearing that what was originally marked convergent strabismus may, after the operations and with glasses sufficiently strong to relieve the asthenopia, become insufficiency of the interni, or even pass into actual divergent squint.

And this leads me to a practical point upon which I wish to insist with some emphasis, and that is that we are prone, in that condition in which strabismus is most common, hypermetropia, to operate too often and at too short intervals.

As a general thing the most careful of us are satisfied with determining the amount of deviation, the state of refraction, amount of vision and accommodation; that is, we make a careful examination of the eye before beginning with the operations, but this once made we proceed in our attempts to remove by surgical means the deformity; that is, we deliberately attack

the effect without paying much attention to the cause of the squint. The effect removed, we then attack the cause by taking into consideration the error in refraction, and we prescribe glasses after one, two or three operations, as the case may be, not with the design that they may be of any independent value in themselves in removing or lessening the squint, for this has been done by the operations, but simply to prevent a relapse from that condition which has been obtained perhaps from repeated tenotomies.

Most practitioners avoid putting on glasses till the wound of the divided tendon is entirely healed, and then, surprised at the little effect gained, resort to another operation within a period of three or four weeks, or perhaps even follow it with a third. I have myself been in the habit of prescribing glasses almost immediately after the operation; but I have not been aware till lately how important it was not to found the indication for them upon even an exact knowledge of the state of refraction gained before the operation, even by the aid of atropine, but upon data furnished *after* the operation from a careful study of the state of the relative accommodation both for the far and near.

I have seen just such results as those mentioned in the preceding case follow, even where no binocular vision existed, and I dare say there are many more which will ultimately go the same way, the sight of which I shall be spared. Patients who have undergone the various vicissitudes from convergent to divergent squint have usually a disinclination to revisit the author of their woes, but there is none of us who does not from time to time get painful examples of each other's failings. The popular fear so often expressed that the eye "may go the other way," though gradually becoming less on account of improved methods of operating, is by no means extinct, either in theory or point of fact. And although we shall probably never be able to measure exactly the effect of a tenotomy, we can at least do every thing in our power to come as near to it as possible, and thus avoid disagreeable consequences, and one of the best ways of doing this is, I believe, to treat more and operate less. To this effect I would suggest the propriety, in all cases of convergent squint in hypermetropic eyes, of reducing as far

as possible the error of refraction before any operative interference is had at all, for the purpose of removing from the interni, as much as possible, the abnormal tension associated with excessive action of the ciliary muscle. By this means I am certain, from my past experience, that we should in the majority of cases reduce the angle of deviation, sometimes even to a great degree, and thus avoid to a considerable extent those numerous "settings-back" of the muscles so detrimental to the easy and lasting performance of their natural functions.

With this brief outline of the manner in which relative accommodation may behave in actual strabismus, I would call your attention for a few moments to a kindred condition—insufficiency of the externi, which is often provocative of homonymous diplopia and intermittent strabismus. Strictly speaking, weakness of the externi recti where there is no anomaly of refraction is exceedingly rare, while in myopia of the highest degree it is of not infrequent occurrence, and in hypermetropia want of proper abductive power is rather the rule than the exception.

We have seen, in the earlier part of these remarks, that if the tension upon the interni was increased the relative accommodation was displaced toward the near point, and it would naturally be supposed that if the tension on the interni was lessened the relative A., instead of being displaced inward, would be removed outward. Now if the externi are weak, it of course follows that it will require less tension on the interni to make the visual lines intersect at a given convergence than if they offered their usual resistance; and if this tension is lessened, it ought to follow that the relative accommodation will be removed further from the near point than under the normal equilibrium of the muscles. But in all cases of marked insufficiency of the externi which I have examined in emmetropic eyes, the field of accommodation was displaced toward the near point, not, as we should expect, removed from it.

These patients have to hold their book near to the eye, some exceedingly so, and the explanation might be sought in the fact that the externi are not strong enough to resist the interni, and thus obtain a proper crossing of the visual lines at even a moderate distance from the eye. But it must be remembered that

these very patients have the power of carrying out the visual lines to parallel axes, as is shown from the fact that their diplopia is rarely if ever constant, while in some cases it is never, as it were, spontaneous, but can only be called forth by the colored glass. Why is it, then, that these patients, if they can overcome the interni to such a degree as to obtain parallel axes, cannot carry out the visual lines sufficient to allow them to read at a distance greater than 14, 12, or even 8 inches, as the case may be?

The explanation of this is, I think, to be found in the action of the accommodation, or rather in the associated action of the ciliary and the interni recti muscles. Under the tension of the ciliary muscle necessary to make reading possible, there is also a corresponding associated tension on the interni, which has the tendency to turn the eye in, and which is counterbalanced in the normal eye by the opposing tension of the externi. If now for any given degree of convergence at which the object is held, the strain put upon the externi in order to resist the interni, while accommodation is going on, is greater than they in their weakened condition can bear, they must of a necessity yield to the superior force; and the result is that the eyes are thus converged to a point nearer than the object, which has to be gradually brought nearer and nearer till a point is reached where the tension on the interni is so great that the externi, though reduced in power, can resist it. But as soon as the accommodation necessary for distinct vision for a near point is relaxed, and with it the associated tension on the interni, the externi are then able, freed from any opposing force, to carry the visual lines out till they become parallel.

Now although a high degree of convergence is necessary in these cases for close work, of course the tension on the interni is not so great for the same degree of convergence where the externi are weak as where they are of normal strength. Thus we see that the relative accommodation may be displaced inward, even when the tension on the interni for every given degree of convergence is reduced.

In emmetropia it is evident that this displacement inward of the field of accommodation can only take place, to any

marked extent, where the insufficiency of the externi is of a very high degree, because as we approach the near point the effective ability of the externi gradually increases, and it requires but little force on their part to maintain the equilibrium of muscular power at the point ordinarily selected for near work. Still that this displacement may take place will be shown by the following case, which I the more willingly cite as I can find but one other like it on record.[1]

C. B., æt. 17, has complained of his eyes "being weak" for over a year, during which time he has been troubled with the common symptoms of asthenopia. He has been wearing a weak convex glass (+1-36), which has given him but slight relief. Latterly all his symptoms have increased, combined with occasional double vision. While reading, the patient habitually holds his book at about 7 inches, but can, with an effort, still read at 12, but not further. The examination gave the following results. Refraction emmetropic (under atropine); V.=1; A. normal. If one eye is covered with the colored glass then homonymous images follow, separated, as measured by prisms, 30° in 20 feet. These images combine at 8 inches, and at 6 vertical diplopia is obtained by a prism, base up. If the candle is held at 8 inches and then moved to either side of the median line 4 inches, homonymous images follow, the images being always on the same plane. The diagnosis was consequently a large amount of insufficiency of the externi; there was, however, no actual strabismus.

The right internus was now divided, and six days after the operation the insufficiency had sunk from 30° to 10° for 20 feet; homonymous images were present only outside of 10 feet, and at 12 inches the candle could be carried all across the visual field without producing homonymous diplopia. The region of distinct vision for near work has been very largely increased, for whereas the patient could not read before the operation at a greater distance than 12 inches, he now reads as far as the type can be seen by the average normal eye, 3 to 4 feet. Ten days later the insufficiency had risen again from 10° to 18° for 20 feet, and it was not till the candle had approached the eye to 18 inches that the homonymous images combined. The ab-

[1] Klinische Beobachtungen Pagenstecher. Drittes Heft, 1866, p. 96.

duction at 12 inches now amounted to 2°, the adduction to 18°. The left internus was now divided, and the results of the examination made three weeks after the last operation were as follows. If the colored glass was used alone over one eye there was no homonymous diplopia, even for 20 feet, nor did this occur anywhere from the distance up to the near point, even when the candle was moved laterally across the field of vision; but if the prism, base up, was added, a small degree of insufficiency (one or two degrees) of the externi was still apparent. The patient is entirely relieved of his asthenopia and diplopia, and can use his eyes to the full amount without experiencing any inconvenience.

In the above case there are two principal points to which I would particularly call your attention. (1.) That although there was no actual strabismus, both interni had to be divided to restore the muscular equilibrium. (2.) That although the patient could, with an effort, carry out his optic axes to the parallel, the relative accommodation was so displaced inward, when the eye was adjusted for near objects, that distinct vision was not possible outside of 12 inches, while near work was usually performed at 7 inches.

To show that this displacement of the relative accommodation may take place when the insufficiency of the externi is the result of operative interference, I would call your attention to the very interesting case presented at one of the late meetings by a member of the N. Y. Ophthalmological Society. The patient was a young lad of about 12 years of age. In this case there was a total hypermetropia of 1-8, with vision = 1. There was an insufficiency of the interni amounting to 8° for the far and 14° for the near. In order to relieve this both externi were divided at the same sitting. The result of this double tenotomy was homonymous diplopia of so great a degree that single vision was only obtained when the object was brought within 6 inches of the eye. This diplopia gradually became less, till at the end of three weeks it only occasionally manifested itself. The patient's total hypermetropia was neutralized, + 1-8 being given. With these glasses vision was 1, and there was no diplopia. The error in refraction having been completely neutralized, the eye might be con-

sidered as an emmetropic eye, in so far that, when in a state of rest, it was accommodated for parallel rays, and consequently had to call forth only that amount of accommodation for a given convergence that a normal eye would; and yet the relative accommodation was very different from that of an emmetropic eye, it being displaced so far inward that the patient could not read outside of 14 inches, while a boy of his age, with vision 1, ought to be able to read common print at 3 or 4 feet.

It would be advanced at once in such a case that the externi had been so weakened by the operations that they had not strength enough to carry out the visual lines, so as to make them intersect at a distance greater than 14 inches. But why have not they the requisite force for this, if they have sufficient to produce parallel axes, which requires a great deal more strength? The only answer to this, that I can see, is the one already given, with a repetition of which I will not weary you.

A further examination showed that the actual abductive power remaining after the operations was, expressed in prisms, only 3°, which is a trifle less than one-quarter what it should be, while the adduction was only 6°, which is also only about one-quarter of what it is in the normal eye. The relative far point for reading is at 14 inches, while the near point is at 6, making the relative accommodation about 1-12, which is certainly one-half, if not one-third, what it should be. Thus we find, in a high degree of hypermetropia, a condition brought about which not unfrequently occurs in exaggerated forms of myopia, where an insufficiency of the externi coexists with that of the interni, together with a reduction of accommodative force.

This reduction in the power of the muscles presiding over the accommodation would lead, we might fear, to some form of asthenopia, either from the ciliary, interni or externi muscles. The fact, however, that notwithstanding the great reduction in force, the proportion between the abduction and adduction remains nearly normal, is very favorable, for if the actual power of both interni and externi increases, the muscular equilibrium between them will probably be maintained.

Although we very rarely find actual insufficiency or even a

reduction of abductive force in emmetropic eyes, in hypermetropia, on the contrary, it is so common as to be in fact the rule. This led Giraud Teulon to express the belief that there is the same inherent tendency in hypermetropic eyes toward weak externi that there is in myopic eyes toward weak interni. Now wherever there is a tendency so strong as to amount almost to a law there must be some cause for it, and the chief causes why the abductive force is abnormally low in hypermetropic eyes are, I believe, two. (1.) That the associated tension of the ciliary muscle in overcoming the error in refraction gives an increased amount of power to the interni. (2.) That the effective force of the externi is *per se* also lessened by the anatomical construction of the hypermetropic eye. In the normal eye, as you are well aware, the externus is inserted further back than the internus, which, in itself, other things being equal, gives an advantage to the interni, and this advantage is disproportionately increased in the hypermetropic, because from the shortened antero-posterior axis the centre of rotation, though relatively more posterior, is more on a plane with the insertion of the muscle, which for this reason has less leverage than in the normal eye.

This want of abductive force may be either actual or apparent. If actual, it depends on some want of power in the muscles themselves, and may be occasioned in three principal ways.

(1.) Through an abnormal preponderance both of volume and force of the recti interni over the externi, which may in themselves be below the normal standard. This condition is generally inherited from parents who have themselves squinted, and in whom, in consequence, the interni have become from constant exercise unduly developed, while the externi, from want of use and from being constantly on the stretch, have lost both volume and vigor.

(2.) From faulty insertion of the muscles, on account of which the interni have the preponderance of power.

(3.) From a state of debility, either temporary or permanent, which has been developed by a constant straining on the part of the externi in order to maintain binocular vision, while the eye is calling forth its accommodation in order to neutralize the error in refraction.

This latter depends on the intimate relation which exists between convergence and accommodation, and which has been more fully dwelt upon in the earlier part of these remarks.

It is evident that in these cases where there is inherent weakness, be it natural or acquired, in the externi, the correction of the error of refraction, though it may give relief, will not remove the whole cause of the trouble; and this is one of the reasons why some hypermetropes, even when provided with suitable convex glasses, still continue to suffer from asthenopia.

Instead, however, of being actual, this insufficiency of abductive force may be only apparent. When it is so, it is due entirely to the efforts of the accommodation to overcome the error in refraction, and disappears as soon as this is corrected by glasses. This will be better explained by an example.

A patient has Hm. = 1-16, Ht., as estimated by the ophthalmoscope, between 1-10 and 1-12. If the condition of the muscles is examined at twelve inches from the eye without the hypermetropia being neutralized by glasses, then the amount of adduction is found to equal a prism of 20°, while the abduction amounts to only 4°. But if the error of refraction is corrected, then the amount of adduction rises to 15°, while the abduction in this particular case undergoes but little change. It is, as a rule, however, slightly decreased.

This shows that the disproportionately low force of abduction is due in this and similar cases not to any idiopathic weakness of the muscles themselves, but to the fact that the nervous impulse, by which the ciliary muscle is able to overcome the error of refraction, is propagated to the interni, which thus throws the balance of power in their favor, and gives them, as long as accommodative efforts are going on, the preponderance of force. From which it follows that the tension on the interni can only be relaxed in these cases by relaxing that of the ciliary muscle. This, as a rule, the unaided eye refuses to do, for the reason that distinct vision would have to be given up. When, however, the hypermetropia is completely neutralized, the undue tension on the ciliary muscle is removed, and, as a consequence, that on the interni. The abnormal resistance

which these latter offer to the action of the externi is thus removed, and these muscles are then left at liberty to bring forth their power in order to maintain binocular single vision, as soon as this is threatened by placing prisms before the eyes with the angle outward.

It often happens that the effect of glasses in increasing, at least to its fullest extent, the abductive force in hypermetropic eyes, is not always obtained at once, even in cases where the externi are not idiopathically weak. It often takes some little time for the eyes to give up the exercise of a certain amount of tension, the employment of which habit has rendered instinctive.

On account of this low degree of abductive power an examination should be made (after the hypermetropia has been neutralized as far as possible) into the condition of the muscles, and if a marked degree of insufficiency of abduction is shown, a tenotomy is, in my opinion, not only justifiable, but necessary, notwithstanding the fact that no actual strabismus exists, and the weight of Donders' opinion against it. The cases requiring operative interference will, of course, be comparatively rare, and the tenotomy must be done, not with the idea of dispensing with the proper correcting glasses, which was Donders' chief objection to it, but with the aim of restoring a normal equilibrium to the muscles.

The next subject which I shall call your attention to, and which I have now only time to briefly touch upon, is the action of the relative accommodation in divergent squint and weakness of the interni, and, as it is in myopic eyes that these affections most frequently occur, my remarks will in a great measure be restricted to that condition.

In myopia the relative accommodation is displaced toward the near point, which is exactly the reverse of what it is in hypermetropia, or, what amounts to the same thing, the proportion of accommodative force actually used is always ~~greater~~ less in myopia than in emmetropia; consequently the tension on the ciliary muscle is always less, while that on the interni is, from the shape of the eye, always greater for a given convergence than in the normal organ. From this it results that the ab-

ductive force is, as a rule, disproportionately great; and, as you are well aware, the first indication in the treatment of insufficiency of the interni is to restore this want of adductive power, by lessening the load which the myopic formation necessarily imposes upon them. The different methods by which this is accomplished, such as tenotomy, the use of prisms and the carrying out the far point by concave glasses, are too familiar to you to need or even to permit any extended comment from me. Still I cannot help thinking that, in practice at least, the important service which suitable glasses may be made to render in preventing the tendency to deviation outward shown by myopic eyes has been much underrated; and in this connection I should like to say a word or two in regard to the effect which concave glasses have on the relative accommodation, through which, I think, their utility in a great measure depends.

As a tendency toward an abnormally great convergence is the chief characteristic of hypermetropic eyes, it must naturally follow that the nearer we reduce a pair of eyes to this condition the greater will be the tendency toward increased convergence of the optical axes; consequently if we have myopic eyes with a tendency toward divergence of the optical axes, we must reduce them to the conditions offered by hypermetropia. This is done in two ways. (1.) By altering the refractive and accommodative condition. (2.) By changing the anatomical ones.

If by means of concave glasses we neutralize myopic eyes, we have, as far as the refraction is concerned, reduced them to a condition of emmetropia, and if the accommodation was good it would be fair to suppose that such eyes would be equal also in muscular force. But this, as Donders proved long ago, is not the case, for in carrying out the far point we have also displaced the relative accommodation outward, and thus in reducing it by glasses to an emmetropic eye for the distance we have changed it for the near into a hypermetropic eye, as far as the accommodation is concerned; that is to say, an increased degree of tension of the ciliary muscle is demanded with small degrees of convergence, which is just the reverse of what it

was before the M. was neutralized. Now allowing that the increased tension of the ciliary muscle in overcoming the glasses is propagated to the interni, in carrying out the far point we have not only decreased the amount of tension demanded of them by lessening the convergence, but we have also increased their effective ability for that convergence.

This will be made clearer by an example. Suppose a myope of 1-7 habitually reads at his far point, that is, at 7 inches. Under these conditions he is using a considerable amount of the tension of the interni with the minimum amount of accommodation, or even with no accommodation at all (Donders). If now we carry out his far point by neutralizing completely or partially his myopia, but so that he can still read with ease at 15 or 16 inches (his near point being no longer at 3, but at about 6), we have by thus reducing the convergence reduced also the amount of tension on the interni to a very large degree. But beside this, by compelling the ciliary muscle, which was formerly idle, to exert its tension in overcoming the glasses, we have gained that amount of force which through its action is always transmitted to the interni. That this is true is proved from the clinical fact that the average adductive force of myopes, who from an early age have worn glasses sufficient to neutralize their myopia, is much greater at their point of near work, and the tendency to deviate outward much less than among those where the error in refraction has not been corrected. For this reason, when in myopia there is any insufficiency in the abductive power, I always make it a rule, whether a tenotomy has been performed or not, to neutralize the myopia, or to come as near this as circumstances, such as the state of the accommodation, amount of vision and age of patient, will permit.

In regard to the second method of relieving the overburdened interni, that by tenotomy, I should have something to say, both as to the indication for and performance of the operation, did not want of time compel me to postpone it till some future occasion.

In conclusion, I would say that the object of these I fear already too extended remarks has been to call attention to

a part of the subject of strabismus which has not yet received the attention which I think it deserves. And it is in this connection that I would suggest that we have hitherto in our treatment of squint paid too much attention to the condition of the recti interni and refraction, and not enough to that of the externi and accommodation.